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THE EFFECT OF THREE STRENGTH TRAINING METHODS ON THE PERFORMANCE OF PRE-PUBESCENT COMPETITIVE SWIMMERS

by

(C) KEVIN PATRICK WHELAN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "The Effects of Three Strength Training Methods on the Performance of Pre-pubescent Competitive Swimmers," submitted by Kevin Patrick Whelan in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

The purpose of this study was to determine the relative effects of strength training of the arms with no such arm strength training on the performance of pre-pubescent (7 to 12 years) competitive swimmers for a 100 metre front crawl swim. Subproblems were the effect of a series of non-resistive flexibility exercises on swimming performance, and the effects of the sex of the subjects in response to the three methods of strength training as measured by arm strength and improvement of swimming performance.

Fifty-four first year competitive swimmers were assigned to six groups of nine each, on the basis of initial swimming time and age. Eight swimmers did not complete the program leaving; a control group of seven, a control group with flexibility exercises of seven, an isometric group of seven, an isometric group with flexibility exercises of eight, a dynamic group of nine, and a dynamic group with flexibility exercises of eight. The analysis was conducted on swimming time to the nearest one-tenth of a second and on force. The strength score was the average of two arm strength tests for each arm taken individually in a simulated mid position of the front crawl stroke.

The analysis of variance technique was used to assess the effect of different variables of sex, flexibility and strength training method on changes in swimming time over an eight week period.

The analysis of variance technique was also used to assess the effect of different variables of sex, flexibility and strength training method on changes in arm strength over an eight week period. Pearson's Product Moment technique was used to correlate the arm strength measures and swimming speeds. It was found that flexibility training had no affect on swimming time. There were no differences between males and females in strength gains or swimming time. There were no significant differences between strength gain and swimming time as a result of three different training groups. All the groups improved significantly in mean arm strength and in mean swimming time. There were low and insignificant positive correlations between pre-training strength and pre-training swimming speed, and between post-training strength and post-training swimming speed. There was no significant correlation between pre to post changes of arm strength and pre to post changes in swimming speed.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

It is generally believed that voluntary muscular strength is an essential component of athletic performance (20, 30, 82, 92). Counsilman and other recognized competitive swim coaches (20, 30, 57) have expressed the opinion that dry-land exercise programs are a must for well rounded training programs of all competitive swimmers. The literature, however, has been inconclusive in presenting evidence to support this training method on pre-pubescent male and female competitive swimmers.

Comparisons of isometric and dynamic strength and methods of training for the gain and maintenance of these two types of muscular strength have been documented by many investigators (9, 10, 28, 38, 63, 32, 6, 75, 77) who sought to prove a conclusive superiority of one type of these two training procedures over the other. Although many advantages are apparent for each type of program, there are no conclusive results which may be used to predict with certainty which method would be more advantageous in any given situation.

In the consideration of any strength training technique, the investigator must remember that the basis for any linear motion achieved by the body, or parts of it, in any competitive medium is always a result of initial angular movement and angular momentum transfer by the body and parts. It is for this reason, that any

apparatus used for strength training, with the objective of increasing power in a specific linear or angular motion pattern should be easily and quickly adapted to simulate resistance in all planes and axes. This very flexible and innovative quality is true of the two active methods of strength training chosen for study and comparison in this thesis.

An obvious practical advantage of the isometric system is the great reduction in time, equipment and complicated instructions necessary to achieve the desired strength gains. Dynamic training, however, through the use of the exergym machine, may be of greater advantage to the swimmer because of the ease with which it can be used to simulate the movement patterns of the various swimming strokes. This mode of dynamic training has shown a wide range of different stresses and tensions adaptable to movements which closely approximate the wet training techniques. This direct reinforcement of required neuromuscular co-ordination may compensate for the increased time and instructional procedures inherent with it.

Flexibility is an area which has been studied by physical educators, and by competitive swim coaches (20, 30, 57, 92). Counsilman (30) emphasized the importance of specific flexibility in the shoulder and ankle joints. He stated that varsity swimmers ranked highest in these two flexibility measures when compared with athletes of other varsity sports at Indiana University. Tihanyi (92), in a recent study, evaluated fifteen maturational determinants against swimming speed. He concluded that shoulder extension strength may

be the most important factor, with composite flexibility the fifth most important factor, when considering the 100 metre freestyle performance.

The Problem

Swimming performance time is a result of many factors of which training, strength, and flexibility are only three. The purpose of this study was to examine and compare the relationship of three different strength training programs and swimming performance in pre-pubescent competitive swimmers.

The three different strength training programs consisted of isometric shoulder extension, dynamic shoulder extension, and superficial shoulder and arm massage, which served as a placebo in the control group. The muscles used in the isometric and dynamic programs were the triceps, biceps, latissimus dorsi, pectoralis major, teres major, subscapularis, flexor carpi ulnaris and palmaris longus.

Subproblems

A number of subproblems were explored as relevant to the main thesis. These are:

1. The comparison of the effects of a series of flexibility maneouvers which were included in the training programs of half of the subjects in each of the major groups.

2. The comparison of the effects of the programs on male swimmers and female swimmers.

Definition of Terms

For the purpose of this study, the following definitions apply:

1. Isometric contraction: An increase in muscle tension without change in muscle length.
2. Dynamic contraction: An increase in muscle tension with a decrease in muscle length.
3. Superficial massage: A light finger tapping on the tissues of the arm and shoulder areas.
4. Pre-pubescent: The period of an individual's development prior to the commencement of mature gonadal function, usually concurrent with the appearance of the secondary sexual characteristics. This period generally lasts until age 15 in the male and until age 12 or 13 in the female (93:493).
5. Exergym: A progressive resistance training device which utilizes two concentric metal cylinders to increase friction, hence tension, on ropes coiled through the apparatus.
6. Swimming performance: The amount of time, in seconds, taken to complete 100 metres front crawl under competitive conditions.

7. Strength scores: The average of two cable tension measurements of each arm, summed to give a combined arm strength score.

Justification of the Study

Training consists of repeated periods of exercise (47) resulting in a more economical and precise execution of the recurring maneouvers (14).

Tihanyi (92) suggested that strength factors were the most important contributors to successful swimming participation among the fifteen maturational determinants that he studied. In his summary and results, he postulated that "It appears that the most efficient experience in terms of performance capabity development for young swimmers comparable to the study sample may not be water training alone" (92:130).

There is a significant lack of literature focusing on the effects of task specific strength training applied to competitive swimmers prior to the commencement of puberty. The writer decided to study the effect of three different strength training programs on the performance of pre-pubescent novice competitive swimmers of both sexes. To elucidate the relative values of dry-land exercise programs and whether they are of sufficient value to be alloted a significant portion of training time is a question with which the practical coach is constantly concerned.

Limitations of the Study

By necessity, the study is limited by:

1. The sample of swimmers used in the experiment. Only 46 subjects were used due to the self-elimination of some swimmers from the program.
2. The puberty evaluation was confined to subjective observation and coach-swimmer consultation.
3. Motivation and learning in the subjects. The motivational levels and learning rates of the subjects were beyond control and probably varied considerably since they were all novices in competitive swimming.
4. The experimenter had control over the subjects only during the times of training and testing, and therefore, could not absolutely eliminate the effect other activities may have had on strength gain.

Delimitations of the Study

1. The study was designed to include only arm strength training techniques which were done isometrically by the use of ropes and chains and dynamically through the use of exergym progressive resistance machines.
2. The total study time was of ten weeks duration, with eight weeks for training and one week each for pre- and post-training measures.

3. The swimming performance test considered was the time taken to complete a 100 metre front crawl swim under competitive conditions.
4. The subjects were not randomly chosen.

CHAPTER II

REVIEW OF THE LITERATURE

Muscular Strength

It is important to begin a description of any muscular action by a description of the muscle being discussed. The physical structure of a skeletal muscle was described in a concise statement by Karpovich:

> A muscle is composed of many thousands of muscle fibers. Each fiber is wrapped in a more or less complete, delicate sheath of connective tissue. A dozen or more fibers are then grouped together forming a primary bundle (fasciculus). This bundle is also wrapped in connective tissue which is tougher and contains collagenous fibers. Several primary bundles, in their turn, form a secondary bundle, which is also wrapped in connective tissue. The secondary bundles form tertiary ones, and so on until the muscle is formed. The whole muscle is covered on the outside by a fascia, which is also made up of fibrous connective tissue. This connective tissue constitutes a strong, framework which, at the end of the muscle, forms a tendon or is attached to the periosteum of a bone. (56:3)

Each muscle fibre contains many parallel myofibrils, which are composed of alternate thin actin and thick myosin filaments (54). These filaments overlap to form alternate light and dark bands, which when aligned with the other myofibrils in a fibre, give the impression of striations across the width of the fibre.

A muscle contraction is initiated by an electrical impulse from a motorneuron, which propagates an electrical stimulus along the surface membrane of each individual fibre. In a manner still not fully understood, this passing membrane potential stimulates the

chemical reaction which causes the actin and myosin to react. This impulse and the resultant myofibril contraction functions on the basis of an all or none principle (7:52). Huxley (54) suggested that in the moment of activation cross-links are formed between the actin and myosin filaments, which successively react to draw the actin filaments along the length of the adjacent myosin filament, and shorten the length of the myofibril.

Voluntary muscle strength or force has been considered a major determinant of athletic performance (31, 30, 20, 92). When physical educators discuss strength it is usually taken to mean "the ability of a muscle or a group of muscles to overcome resistance or create tension-push, pull or lift" (30:276).

The three types of measurable muscle strength are dynamic concentric, dynamic eccentric and isometric (7). Within the scope of this study, only dynamic concentric and isometric contractions will be considered. The term dynamic concentric was chosen over isotonic in view of the fact that a muscle exerts different amounts of force as the bone levers to which it is attached become shorter or longer (7:74).

Muscular power can be expressed in terms of applying force, with varying degrees of efficiency, to accomplish the task of moving an external object or the body itself. Improved performance is accomplished by increasing the velocity of movement through increased skill or efficiency in the application of the force, or by increasing the available force.

Cratty (31:219) listed ten factors which contributed to the performance of gross motor skills. These were: strength, dynamic strength or energy, ability to change direction, flexibility, agility, peripheral vision, good vision, concentration, understanding the mechanics of movement, and absence of emotional complications. Cratty considered strength important as evidenced by its rank on the list of determinants.

Counsilman stated that "The physical conditioning required for good swimming performance is made up of three major components: (1) strength, (2) endurance, and (3) flexibility (30:276). It is of no surprise that Counsilman has trained most of his swimmers using additional dry land strength programs. He has stated that "some swimmers who held world records and did not have dry land exercises would have performed better had they had such programs" (30:309).

Carlile (20) also supports the use of dry land exercises for the strengthening of competitive swimmers. He gave the opinion that "strength and flexibility are very important factors for the competitive swimmer and both can be improved with special exercises" (20:49). On the basis of his experience he also stated that "there are few top swimmers in the world who do not work for strength out of the water in addition to their strenuous training in the water" (20:49).

Tihanyi (92) evaluated the relationship between fifteen maturational determinants and swimming speed in six competitive races of eleven to twelve year old age group swimmers in the 1970 Alberta Age Group Championships. On the basis of his analysis of these 36 swimmers, he stated: "The various strength measurements were the most important contributors to successful participation among the maturational determinants" (92:128). The extremely homogenous nature of his subjects somewhat limited the range and power of his conclusions.

Studies of Isometric Strength Training

Hettinger and Muller (48) reported a series of experiments in which one isometric contraction of a muscle group against an immovable resistance caused an increase of muscle strength. The maximum isometric strength of the elbow flexors and extensors at 90^{o} of elbow flexion was established on the first day of the week and for the next five days the subjects performed the exercises. The intensity and the number of contractions were co-varied in order to determine which combination was most effective for strength increase. They concluded that the optimal method for increasing strength (maximum of 5% per week) was a single six second contraction of 67% of the subject's maximum isometric strength. The small sample size of nine subjects may have contributed to the causes of these conclusions which were not repeated by later investigators. (59, 67, 74, 81).

Muller and Rohmert (67) theorized a level in an individual's training at which further increase in strength is impossible. They termed this state the "limiting strength". They assumed that limiting strength meant the same state of ultimate training for every muscle in the group being exercised. It followed from this, that the relative strength of an individual at any given time, was his strength as a percentage of limiting strength. They suggested that the less trained a muscle was at the beginning of a training period, the greater the rate of gain of strength. They compared the effects of four isometric training programs on the rate of strength gain from 80% up to 100% of limiting strength. It was found that the group training by multiple daily maximal contractions totalling thirty seconds took the least amount of time of four weeks to reach limiting strength. The group training for one six second daily maximal contraction attained limiting strength after five weeks. It took six weeks for the group using one daily maximum contraction held for one second to reach limiting strength. The group using one daily six second contraction at 67% of maximal strength took nine weeks to reach limiting strength. To follow the course of strength increase and to adjust the training force for the sub-maximal group, a maximal test contraction was performed each week. This weekly maximal test was itself a training stimulus (67).

Liberson and Asa (59) found that isometric training for 20 repeated six second maximal contractions per day increased strength

by 203%. This was opposed to an increase of 174% in a group which trained at a single daily maximal contraction for six seconds. These powerful results were limited by the small sample size of their groups, which totaled 26 subjects.

Berger (10) compared the effect of varied sets of static training on dynamic strength. He compared three groups, which were exercised at two positions of a static bench press for one, two and three sets held for eight seconds at maximum effort. He found by measuring the single repetition maximum of a dynamic bench press, that the different methods resulted in approximately the same improvements in dynamic strength.

Studies of Dynamic Strength Training

In 1945, DeLorme (36) developed a procedure to strengthen atrophied musculature. His subjects were patients who had undergone bone and joint surgery. He adapted a table with lever and pulley mechanisms on which most affected muscle groups could be exercised. Once each week the maximum amount of weight that each subject could lift was determined. This he termed the one repetition maximum (1RM). He then measured the amount of weight the subject could lift ten times only, and called it the 10 repetition maximum (10RM). He required each of his 300 subjects to lift seven to ten sets of the ten RM for the four remaining days of the training week. His method was effective for increasing muscle strength and range of motion of

the affected joint by progressively raising the ten RM each week.

DeLorme (36) modified his original method in 1948. The modified version proposed only three sets of ten contractions each day. The first, second, and third sets consisted of 50%, 75% and 100%, respectively, of the ten RM. He did measure the one RM and the ten RM each week, as he did with the original method.

Today, most dynamic exercise methods used primarily for strength increase are patterned after the DeLorme basic concept of exercising muscles using the overload principle, or as Counsilman stated "a greater load or stress is placed on the muscle than it is normally exposed to" (30:280).

Berger (11) studied the effect of varied dynamic weight training programs on strength. The experiment was conducted with the bench press lift as the dependent variable. He compared nine different training groups of one, two and three sets; and two, six and ten maximal repetitions per set, with approximately twenty subjects in each group. All of the groups trained three times a week for a twelve week period; during which he took the one RM in the bench press at the beginning of training and at three week intervals until the end of training. He concluded that all training methods increased strength significantly (P=01). Training in the group which performed three sets of six repetitions seemed to be the optimum for increasing strength over the duration of the twelve week schedule.

Studies of Dynamic Versus Isometric Strength Training

Liberson and Asa (59) studied the effects of isometric and dynamic strength training on 26 subjects. All groups trained four times a week using the abductor digiti quinti muscle. The dynamic group trained on three sets of 50, 75 and 100% of the ten RM, while half of the other group trained as two subgroups using a single maximal six second contraction, and twenty maximal six second contractions. They found isometric to be superior in strength increase over the DeLorme method; the repeated isometric contractions were significantly better than the single isometric contraction for strength increase.

Meadows (63) trained 60 subjects isometrically and 60 subjects dynamically on elbow flexors. Both isometric and dynamic were subgrouped; fifteen in each of four groups, trained two, three, four and five times per week for four weeks. Dynamic training consisted of exercising to exhaustion at 30% of maximum strength. A maximum effort for six second pulls was the isometric training. He reported that the isometric program caused a greater number of subjects to gain significant amounts of strength. The five training bouts per week were most beneficial for strength gain.

Danielson (32) compared the effects of concentric, eccentric and isometric training on maximum voluntary strength of the leg extensors. He compared equal groups of ten subjects that trained three times a week progressing from six to eighteen contractions per session; all contractions taking six seconds to complete. He

concluded "Isometric training proved to be the most effective in improving strength of all three types over a training period of seven weeks" (32:97).

Knee extensor strength training of high school boys in Edmonton was conducted by Richardson (77) in 1963. Sixty grade ten boys were divided into three groups. One group was trained isotonically-isometrically, the other was trained isometrically at knee angles of 115 degrees and 135 degrees of flexion. He found that the isotonic group increased significantly over the isometric group at the 135 degree angle and that there was a significant difference between the two groups at the 115 degree angle. Both groups increased significantly over the control in both strength and endurance or holding time.

Morris (66) compared the effects of isometric and dynamic training programs on quadricep strength and performance in a middle distance running event. His four groups of 30 subjects each, consisted of; interval running and dynamic strength training, interval running and isometric strength training, control A interval running, and control B with no training. The groups trained three times a week for eight weeks. He observed a significant improvement in the first two groups, plus the dynamic program improved strength and running time more than the isometric program did.

Darcus and Salter (33) compared gains in strength resulting from isometric and dynamic strength training programs in pronation and supination of the forearm. The two groups made use of unilateral

training of 30 contractions per day for five day and for 28 day training periods. They found no significant differences between the two training methods. The study did show non-significantly greater increases for the dynamic over the isometric training. The investigaters, unfortunately, did not take into account the effect of the eccentric training which resulted from the subjects slowly releasing the weight after concentrically raising it, which may have affected the final results.

Dennison, Howell and Morford (38) equated two groups of ten subjects on arm strength index scores as indicated by the maximum number of arm chin-ups and arm dips that each of the subjects could complete. The subjects were then assigned to equivalent isometric and dynamic strength training programs consisting of two sessions a week for eight weeks. They concluded that both groups improved arm strength index and that both groups improved significantly in muscular endurance of the upper arms, with slightly greater gains in mean strength for the dynamic group. It was also suggested that the reduced time necessary for the isometric program was a positive factor of that particular program.

The relationship between changes in strength of the quadriceps muscle and changes in reaction time and movement time, in a knee extension movement was studied by Kerr (56a). He trained 45 male physical education university students in three groups of equal mean RT and MT. One group served as a control group, one as

an isometric training group and the other as an isotonic group. The isometric and isotonic groups trained four times a week for five weeks. The isometric group was trained for three, six second maximal contractions at three angles of 115°, 135° and 155°. The dynamic group lifted a maximal weight from the 90 degrees flexion position to the 165 degrees extension position over a six-second time period, after which the weight was removed to avoid any eccentric training stimulus. This was repeated twice more after rest periods of ten and twenty seconds. If the subject could successfully lift this weight, another one and one quarter pounds was added to establish a new maximal weight. He found neither speed of movement nor reaction time was increased as a result of the training. Both groups gained significantly in strength over the controls, but there was no significant difference between the gains of the two groups.

Coleman (28) compared the weekly strength changes produced by training the forearm flexors of one limb isometrically and the contralateral limb dynamically in 23 subjects. Eleven subjects performed the dynamic exercises with the left arm, and the other twelve subjects performed the same dynamic exercises using the right arms. The isometric exercises were performed on the opposite limbs of each of the same 23 subjects. The dynamic group trained unilaterally for two sets of five RM starting from 110 degrees of elbow extension using the weight for the five RM. Increments of weight were added

to both methods as the subject increased the five RM. Training occurred three days a week for twelve weeks. Coleman analyzed the weekly percentage changes and final mean scores and concluded that gains in muscular strength following isometric and dynamic training occur at a similar rate.

Specific Versus Non-Specific Training

The theory that the central nervous system can affect muscular strength without training the affected muscle group is a popular concept. Cratty (31:290) stated that "Transfer from hand to hand of a skilled act, to some degree always occurs. It is usually taken to indicate that skilled performance is a function of central rather than peripheral processes in the nervous system." From his survey of the research, he reported that:

> It was found that as much bilateral transfer occurred in a one-handed manipulative task as was derived by the subjects when they simply watched another individual perform the task first! (31:290)

In his study of the effects of dynamic versus isometric leg extensor training on motor performance in a vertical jump, Berger (9) trained four groups, with a total of 89 subjects, three times a week, for eight weeks. The first group trained dynamically on one set of ten squats per session at the ten RM level, while the second dynamic group trained using ten jumping squats at 50% of the ten RM level per session. The isometric group trained with six second maximal contractions at two positions. The first was with

upper legs, parallel to the floor, and the second position was extension of the knee at 135 degrees. The last group trained at the level of ten vertical jumps per session. He found significant differences in vertical jump performance (P=.01) for both dynamic groups, with no significant difference in the performance of the isometric group (P=.05). These results indicate that the dynamic progressive resistance training, which was similar to the task, was the most effective for increasing jumping height performance.

Some investigaters agreed that direct practice or task specific training is the ideal form of training for any complex activity. Roberts and Alspaugh (78) trained 36 subjects, in two equal groups, for treadmill walking and bicycle riding at increased intensities, for three times a week over a five week period. Pre- and post-tests of PWC_{150} were administered to each group. In the post-training testing, both groups performed tests in bicycle riding and treadmill walking. It was found that the treadmill trained group, which were tested on both the treadmill and the bicycle ergometer, had no significant difference in measured gains of cardiovascular function. The bicycle trained group, which was tested the same way, sustained gains in functional cardiovascular response which were significantly greater than the improvement shown when measured via the treadmill test.

Murphy (69) trained the quadriceps extension function in three groups of dynamic, isometric, and non-trained controls. He

trained the 24 male subjects in each group for three sessions per week over a nine week training period. He tested the effect of each training type on the quadriceps function by means of a static test and a dynamic test. The static test was a measure of isometric tension exerted by the lower leg at an angle of 135 degrees. The dynamic test consisted of measuring the rotary torque developed under four varied loads of resistance, of 50, 40, 30, and 20% of initially recorded isometric strength in pounds of tension. He found that neither training group was able to exert a greater torque after training than they had prior to completing the programs. He concluded that there was little or no relationship regarding gains in static strength and changes in the ability to perform an act that generates torque.

Schultz (82) tested the effects of different training methods on performance in a 60 yard run, broadjump, and zig-zag run. The training groups were weight-training (WT), direct practice (DP), and repetitive sprinting (RS), together with three combined groups of RS-DP, WT-RS and DP-WT. Each group consisted of twenty university freshmen, who trained three times a week for four experimental time periods: a nine week period (the first eighteen training sessions), a vacation period (due to spring recess of thirteen days), a post-vacation period (training resumed for three sessions); a total experimental period (twenty-one sessions plus the vacation). He concluded, within the limitations of his study, that the direct practice alone or in combination with

the training of repetitive sprinting and weight training was superior to weight training for increasing standing broadjump, zig-zag run, and 60 yard dash performances. He found that the vacation period and the short post-vacation training period did not significantly affect performance, except in the case of zig-zag run, from the performance immediately after the initial nine week period. These conclusions give further evidence to the concept that repetitive motor performance of a task is the best training for that task.

Bender and Kaplan (7a) suggested that isometric contractions must be executed at various angles throughout the range of motion rather than at one specific point or angle. This they found to be necessary for improving the strength of the affected muscles throughout the whole range of motion of the joint.

Counsilman concurred with Bender and Kaplan when he stated:

> A muscle that is contracted isometrically in only one position will tend to become strongest in that position. In order to develop strength through the full range of movement of a muscle, it is recommended that a series of isometric contractions be used at various angles throughout the full range of movement. The name applied to a series of this kind of isometric contractions is intermediary contractions. (30:283)

Studies of Strength in Relation to Swimming

Tihanyi (92) examined the contributions of fifteen independent variables, which he termed maturational determinants, on the swimming performance of 36 subjects in six swimming events. All of the

subjects were in the eleven to twelve year old age group and all had qualified to participate in the 1970 Alberta Age Group Provincial Championships. He recommended that strength, as a composite of shoulder, knee, ankle and trunk strengths, were the most important contributors to successful swimming performance. He suggested that shoulder strength was the most important determinant of success in the 100 metre freestyle swim. He suggested in his conclusions that:

> Perhaps the development of specific motor patterns, characterized by the different swimming strokes, which require specific strength and flexibility qualities, may be the avenue to a more successful but less stressful training regimen for young swimmers. (92:130)

Counsilman (30:27) performed an experiment to test the contribution of the flutter kick to forward propulsion in the freestyle stroke. He attached a variable speed towing device to a strain gauge platform at water level. The varying forces on the tow rope were measured at different rates of tow with the swimmers gliding only and with the swimmer flutter kicking at maximal force. He found that the flutter kick, when used at maximum effort decreased the tension on the rope, for speeds of under five feet per second. When towing speed became greater than five feet per second, the kick contributed nothing to the speed of tow and actually increased the drag on the tow rope for some individuals.

Counsilman's study above seemed, on a superficial level, to be contradictory to his previous advocation of reduced emphasis

on the kick. This was explained by Counsilman's estimation of the flutter kick as primarily a stabilizing rather than a propulsive component. The remarkable performance of swimmers trained by Counsilman seems to give practical, as well as theoretical weight, to his estimation of the role of the flutter kick in swimming front crawl.

Studies of Pre-Adolescent Training Effects

Brown et al. (15) reported that pre-adolescent girls were capable of adapting to cross-country endurance training, of cardiovascular and muscular functions, in a fashion very similar to adults. He monitored the endurance training programs of twelve girls between the ages of eight and thirteen years, who had at least one year experience in training with track clubs. Eight female track athletes who did not train for endurance running acted as controls. The training programs varied among the three participating track clubs, but generally sessions were one to two hours long on four or five days of the week, for a total of twelve weeks. He found that mean maximal oxygen uptake at maximal work loads increased 26% in the experimental group with no change in the controls. There were no observable detrimental effects to the training group.

Wilmore and Sigerseth (95) determined the physical work capacity of 62 girls between seven and thirteen years using a step increment test on a bicycle ergometer. The values obtained for

the various parameters measured, including submaximal and maximal oxygen intakes and submaximal and maximal heart rates, were similar to previously measured values they found for boys of approximately the same ages. This suggested that within these ages, there were no basic differences between the sexes in their physiological responses to maximal exercise. Maximal heart rate was independent of the person's physical work capacity. On the basis of this finding it is doubtful that this parameter could be used with any validity to predict maximal oxygen uptake. This is a deviation from the relative predictability of adult MVO_2 from submaximal parameters.

Murphy (68) measured the strength of a selected group of muscles on 657 elementary school boys for the purpose of studying the pattern of muscular development in boys ages six to eleven years. The instrument he used to measure muscle strength was the cable tensiometer, and the muscle groups tested were the elbow flexors, elbow extensors, shoulder flexors, hip flexors, hip extensors, and knee extensors. Total strength(i.e. the sum of all these measures)was also computed for each subject. The conclusions were as follows: (1) the pattern of growth in strength is an irregular one for the six age brackets studied (6, 7, 8, 9, 10, 11 years); (2) the pattern of growth in strength is irregular as height increases; (3) the percentage contribution made by each muscle group fluctuates slightly through the age levels, and through the

height levels. These results suggest that subjects of this age range will generally follow the same trends in response to cardiovascular and strength training as do adults. These results, however, do illustrate a greater degree of unpredictability when dealing with physiological measurement of children under the age of twelve as opposed to older subjects.

Studies in Tensiometric Strength Measurements

Clarke (25) conducted experiments on the comparison of instruments for recording muscle strength using the Wakin-Porter strain gauge, a Newman myometer, spring scale and the cable tensiometer had the greatest precision for strength testing. He concluded that the cable tensiometer was the most stable, precise and useful of the instruments he tested.

Huntington (53) measured total strength by using four cable tensiometer tests which were administered to 150 elementary boys. High, middle, and low strength groups, containing fifty boys each, were formed from the corresponding cable tensiometer test scores. He then administered motor fitness test batteries which included: an agility test, a cardiovascular endurance test, a power test, a strength and muscular endurance test and a running speed test. He concluded that relationships between strength and total test batteries showed low positive or negative correlations at all strength levels. He found the cable tensiometer to be an accurate device for measuring strength, but not practical for

predicting achievement on the selected motor fitness tests, on the basis of the type of strength it measures.

Chui (22) studied the comparative effects of isometric and dynamic weight training exercises on: (1) strength and (2) speed of execution of a single movement. He strongly supported the use of the cable tensiometer as the instrument best suited for strength measurement by using it to obtain eight strength scores for each of his ninety-six, male, university subjects. The eight strength scores included: elbow flexion (right), elbow extension (right), shoulder vertical flexion (right), shoulder horizontal flexion (right), trunk flexion, trunk extension, hip extension (right), and knee extension (right). In comparing the three experiment groups that he tested, he concluded that there were no statistically significant differences, at the five percent level of confidence, in the gains in strength and in the accompanying gains in speed of movement against no resistance and against resistance.

Burnham (19) investigated the relative effectiveness of the two different methods of exercise on the development of muscular strength in individuals with different levels of strength. His subjects consisted of 148 college males who voluntarily participated in a ten week exercise program. The subjects participated three days a week in one of the following exercise programs: isotonic exercises for ten weeks, isotonic exercises for five weeks followed by five weeks of isometric exercises, isometric exercises for ten weeks, or isometric exercises for five weeks followed by five weeks

of isotonic exercises. The cable tensiometer was used to measure muscle strength before, during the middle, and at the end of the training program. The four strength tests used were: arm flexion and forearm extension, arm extension and forearm flexion, thigh and leg extension, and trunk flexion. It was concluded that there were no significant differences between isometric and isotonic contractions in the development of muscular strength either for the group as a whole or for the different strength levels.

On the basis of the previous studies, the cable tensiometer was chosen as the measuring instrument for the present study due to its ease of use, accuracy, and equal bias toward measurement of all treatment groups.

Flexibility

Flexibility is an area which has been studied by physical educators generally and specifically, by competitive swim coaches (20, 30, 57, 92). Counsilman (30) emphasized the importance of specific flexibility in the shoulder and ankle joints. He stated that varsity swimmers ranked highest in these two flexibility measures when compared with athletes of other varsity sports at Indiana University. Tihanyi (92), in a recent study, evaluated fifteen maturational determinants against swimming speed. He concluded that shoulder extension strength may be the most important factor, with composite flexibility the fifth most important factor, when considering the 100 metre freestyle performance.

CHAPTER III

METHODS AND PROCEDURE

Subjects

Subjects for the study were 46 first year competitive swimmers who trained with the Cascade Swim Club of Calgary from the beginning of October 1973 until the end of May 1974. All of the subjects were within the age range of seven years (89 months) and twelve years (147 months). The subjects were screened by subjective visual observation and, in some instances, by coach-swimmer consultation to eliminate those who had begun pubertic changes, as evidenced by the secondary sexual characteristics, and menarche in the female subjects. Fifty-four subjects out of a possible eighty-three were arrived at by this process, however, four subjects in the control group, three in the isometric group and one in the dynamic group did not complete the program. This left a total of 46 subjects, fourteen in the control group, fifteen in the isometric group, and seventeen in the dynamic group. The subjects were of both sexes and participated in no organized athletic activity other than the competitive swim training.

Experimental Equipment

The experimental equipment consisted of five exergym$_R$ dynamic exercises (Figure 1), five isometric training exercisers (Figure 2), five three-eighths of an inch metal training hooks,

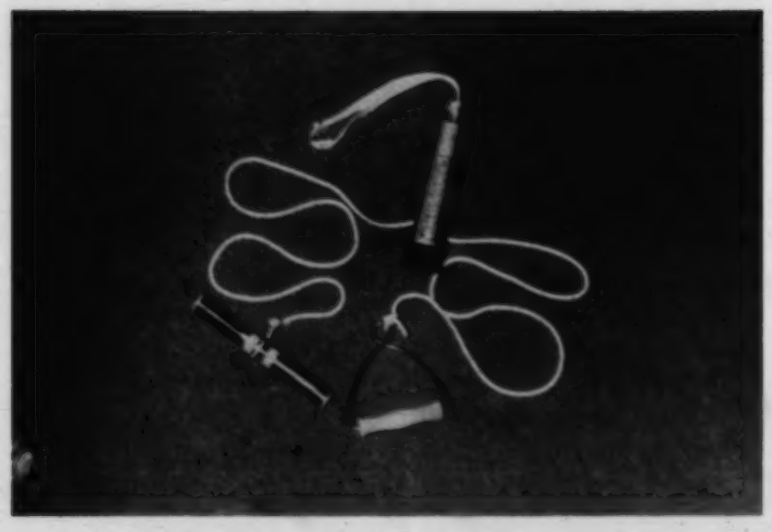

FIGURE 1 EXERGYM$_R$ EXERCISOR

FIGURE 2 ISOMETRIC EXERCISOR

which were permanently anchored to the concrete walls, five wooden benches, a T5 aircraft cable tensiometer, and an eighth of an inch diameter steel cable.

The Exergym$_R$ machine (Figure 1) is a device which makes use of friction to vary resistance. A rope passes through two apertures on either side of an external cylinder. Between the two apertures the rope is coiled around an inner cylinder. The cylinder varies the friction and the resistance on the free movement of the rope. An external dial setting enables the user to select increasing amounts of resistance to the rope movement.

The metal T5 aircraft cable tensiometer, manufactured by the Pacific Scientific Company, (Figure 3) measures the amount of tension that is being exerted along the length of a steel cable. The range of measurement of the instrument can be adjusted by using different sizes of riser and by using cables of different diameter. For the purpose of this study, a number 1 riser and an eighth of an inch steel cable were used for measuring arm strength. The instrument was calibrated to yield measurements in pounds of tension for each reading on the dial face. The calibration values are presented in Appendix A.

The isometric exerciser consisted of a five and a half foot length of non-elastic rope, with a hand grip attached to one end, plus a slip knot at the opposite end (Figure 2). The length of this exerciser was kept constant throughout each session and for the entire duration of the program.

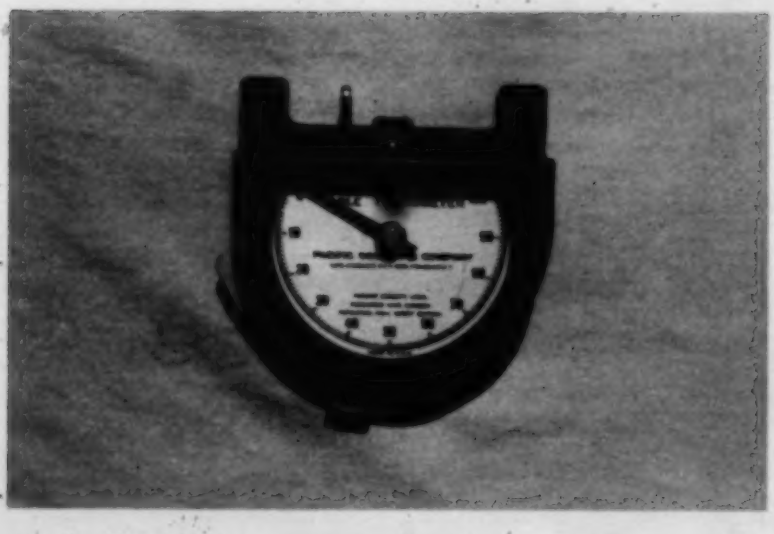

FIGURE 3 MODEL T5 AIRCRAFT CABLE TENSIOMETER

Experimental Design and Training

Since the subjects had no previous experience in training for competitive swimming, it was to be expected that they would be quite diverse in their responses to the physiological demands of the training. In order to compensate for this, the subjects were all trained on a swimming program exclusive of weight training and flexibility exercises for the first seven weeks of the season.

The subjects were assigned to three groups according to initial swimming speed. The resulting three groups had statistically identical mean times taken to complete a 100 metre freestyle swim. The groups consisted of an isometric training group, a dynamic training group, and a control group. Each of the three main groups were subgrouped into flexibility exercises, and non-flexibility exercises, using half of the subjects from each of the main groups to represent this sample, The six groups, therefore, consisted of: isometric training with flexibility exercises, isometric training without flexibility exercises, dynamic training with flexibility exercises, dynamic training without flexibility exercises, a control group with flexibility exercises, and a control group (See Appendix D). Subjects trained consistently in the same training room three sessions per week, on Monday, Wednesday and Friday during the same time period each day.

The isometric group trained using two six second maximal contractions at each of three arm positions for a total of six six second maximal contractions, which were done with each arm. These

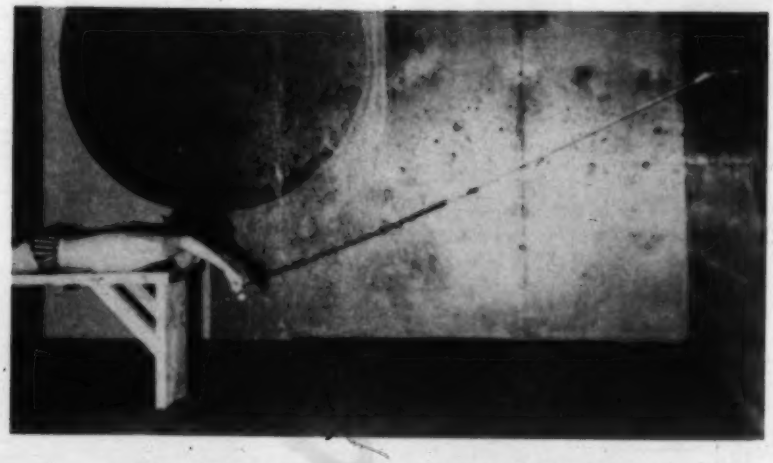

FIGURE 4a ISOMETRIC CATCH POSITION

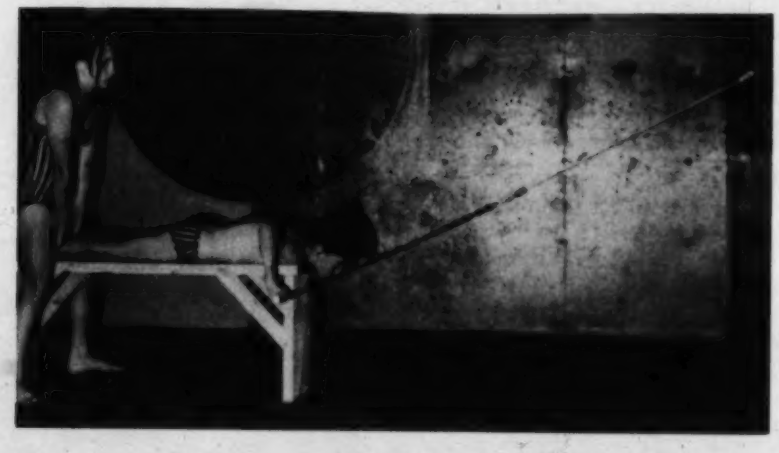

FIGURE 4b ISOMETRIC MID POSITION

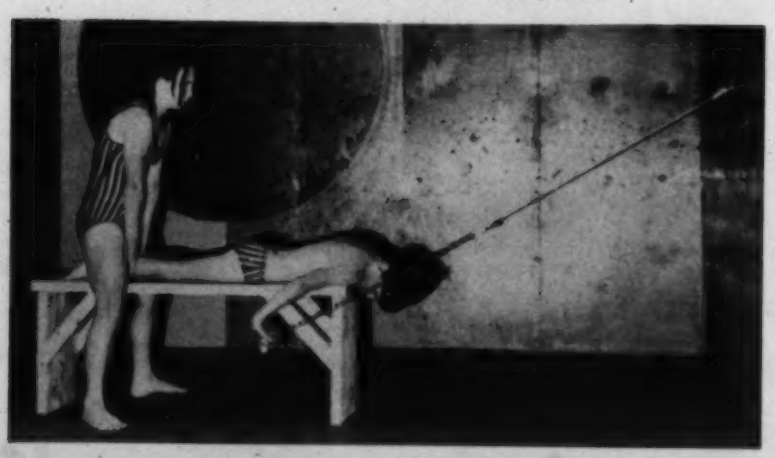

FIGURE 4c ISOMETRIC ARM POSITION IMMEDIATELY PRIOR TO RECOVERY

positions simulated motions in the front crawl stroke and were equivalent to the point of entry of the hand into the water (Figure 4a), the arm position midway through the stroke (Figure 4b), and the arm position just before arm recovery (Figure 4c). The mid position for the purpose of the exercise was chosen as the point at which the elbow was at 90° flexion and the upper arm formed an extension of the line of the shoulders. The isometric subjects completed one contraction with the right arm in the beginning position, and then rested that arm for ten seconds while they performed the same contraction with the other arm. This was repeated once more for each arm in the initial position. This procedure was repeated for the remaining two arm positions.

The dynamic group trained for six sets of twelve arm cycles per set. The twelve cycles were performed alternately by the arms so that each arm accomplished six repetitions per set. A single arm cycle or repetition was the resisted motion from the initial catch position of the hand with the arm extended over head (Figure 5a), through the mid position (Figure 5b), to the arm position just before recovery (Figure 5c). The arm was recovered back to the starting position while the alternate arm began its cycle.

The six repetition maximum (6RM) was that resistance setting, on the adjustable dial of the Exergym$_{R}$, which the subject could complete a maximum of six repetitions with each arm. It was

FIGURE 5a DYNAMIC CATCH POSITION

FIGURE 5b DYNAMIC MID POSITION

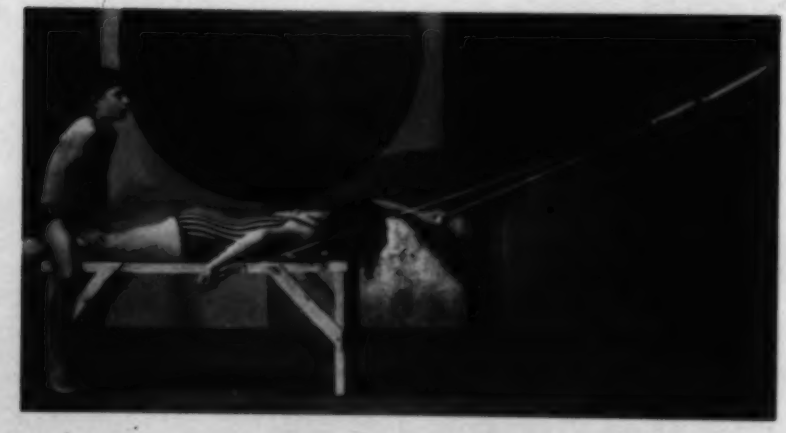

FIGURE 5c DYNAMIC ARM POSITION IMMEDIATELY PRIOR TO RECOVERY

decided to consider these dial settings as the reference point for each subject's six RM. The reasons for this choice of six RM value, as opposed to an absolute measurement of pounds, was threefold: intra-machine friction was subject to change as the rope became worn; inter-machine variations were uncontrollable due to rope friction variance and individual specifications of each $Exergym_R$; such a method of determining the six RM was more easily remembered by each individual.

The investigater attempted to minimize variation due to intra-machine friction changes by replacing the ropes after completion of the first four weeks of training. In order to minimize variation between machines, each machine was numbered and each individual used the same machine throughout the program.

Since the six RM was the resistance value and the dial setting for the final set, it was the reference point used to determine the dial setting for the preceeding five sets. If the dial setting for a subject's six RM was twelve, then the subject counted back ten dial settings to two and used that dial setting for the first set. An increment of two was added to the dial setting for each succeeding set, with the second set performed at a dial setting of four, the third set at six, the fourth set at eight, the fifth set at ten and the last set at twelve, which, for this hypothetical case, was the six RM value.

Throughout the program the six RM was re-determined weekly. The subject had to meet three criteria for the re-established six RM:

first, the resistance was the maximum that could be pulled for six times by each arm; second, it had to be performed at a cadence of one arm pull per second for twelve seconds for a total of six seconds per arm per set; and third, all of the six repetitions for each arm had to be performed. In this manner, the duration of exercise for each dynamic subject was equalized with the time taken by each isometric subject to complete six maximal isometric contractions held for six seconds each.

The control group of fourteen subjects underwent no strength training other than the swimming program itself, which was identical for all groups. The experimenter felt that a placebo program was necessary to compensate for any motivational effect that non-training might have had on the control subjects. With this in mind, a superficial massage was performed on each subject for the same amount of time that the others trained. This consisted of light finger tapping on the arms, legs and shoulder girdle of each member of the control group. No penetration was permitted beyond the superficial layers in order that deep muscles received no training effect.

Testing Procedure

All of the subjects were tested in the same exercise room at the same time of day as that of the training periods, which were from 4:00 p.m. to 5:45 p.m. Monday, Wednesday and Friday. Each

subject was tested by the experimenter, who was the only person, other than the subjects, present during the tests. A subject was asked to lie prone on a testing bench, which was adjusted to the cable length by the experimenter. The subject was asked to pull on the hand grip attached to the cable for a steady maximum contraction, with the elbow at 90^{o} flexion and upper arm forming the extension of the shoulder line. The single arm strength reading was thus registered on the cable tensiometer (Figure 6).

Two subjects were measured alternately. The experimenter took one reading of the right arm strength of subject one, followed by one reading of right arm strength for subject two. In this way the subjects were given 30 seconds rest between measurements. This method was repeated for left arm strength measures of each subject, and then repeated once more for right and left arm measures. The resting subject served as a stabilization force while the other subject was being tested. This was done by sitting on the back of the legs of the subject being tested. This ensured that the subject could not change position during the testing contraction.

The subjects were tested for arm strength on a total of four trials for each arm. Two of the trials for each arm were measured before the commencement of the strength training program. These two arm strength trials were averaged and added together to give a pre-training composite strength score. That is, the average left arm strength score was added to the average right arm strength

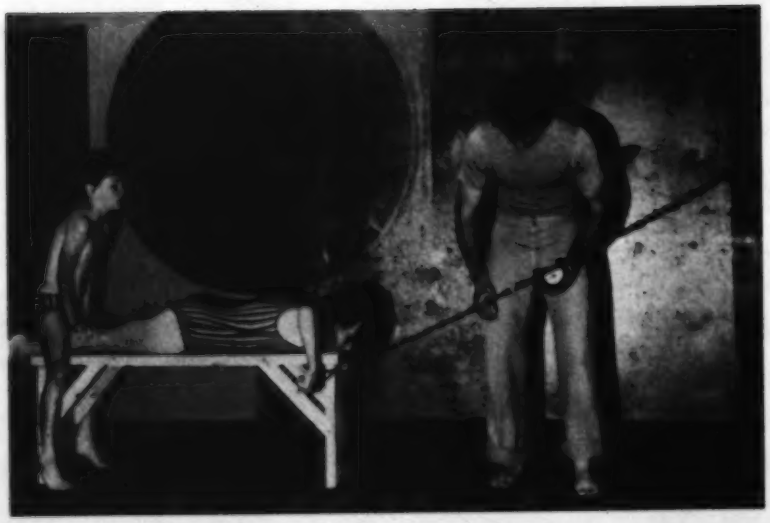

FIGURE 6 ARM STRENGTH TESTING TECHNIQUE

score to yield an average composite score for arm strength. Similarly, two strength measures for each arm were taken immediately after the conclusion of the training program to give a post-training composite strength score. The pre-training swimming performance time for each subject was the time taken to complete a 100 metre freestyle swim under competitive conditions before initiation of the exercise program. The post-training 100 metre freestyle time was determined for each subject during the week immediately following the last week of the strength training program, and was also swum under competitive conditions.

Calibration of the Apparatus

The cable tensiometer was calibrated by comparing the indicated deflection on the dial face to a known load on a tensiometer calibrator. The calibrator, provided by the Faculty of Engineering, University of Calgary, consisted of a cable connector attached directly to the tension measuring scale at one end, and to a fixed hook at the other end. The calibrator readings in pounds of tension, from 1 to 50, were noted and calibrated to the corresponding tensiometer readings.

Statistical Treatment

Repeated measures of arm strength and swimming time were taken prior to and after the strength training period for each of the subjects. Pearson's Product Moment correlation technique was

used: i) to determine the reliability of tensiometric measures, ii) to examine the correlation between strength and swimming performance before strength training, iii) to correlate measures of strength and swimming performance after strength training, and iv) to determine the correlation of the difference between pre- and post-arm scores to the difference between pre-and post-swimming performance times.

The obtained data were subjected to the following analyses of variance:

1) A 2 factor ANOVA of flexibility effect versus pre- and post-training swimming times for all groups combined.
2) A 2 factor ANOVA of flexibility effect versus pre- and post-training swimming times for the control group only.
3) A 2 factor ANOVA of sex versus flexibility effect on post-training swimming time.
4) A 3 factor ANOVA of sex effects versus training methods pre- and post-arm strength scores.
5) A 3 factor ANOVA of sex effects versus training methods versus pre- and post-swimming times.

In order to equalize the number of subjects in each cell, for (4) and (5) above, the data for three subjects from the dynamically trained group and for one subject from the isometrically trained group were

randomly deleted.

6) A 2 factor ANOVA of the three training methods versus pre- and post-arm strength scores.

7) One factor ANOVAS of the different training methods for each of the pre-training strength scores and post-training strength scores.

8) A 2 factor ANOVA of the three training methods versus pre- and post-swimming times.

9) One factor ANOVAS of the different training methods for each of the pre-training times and post-training swimming times.

The programs used for analyses of variance were the ANOV30, a three way analysis of variance with repeated measures on the third factor; ANOV25, a two way analysis of variance; ANOV23, a two way analysis of variance with repeated measures on the second factor, and ANOV15, a one way analysis of variance. All of these programs were found in the library of statistical programs of the Division of Educational Research Services at the University of Alberta.

Pearson's Product Moment correlation was performed by means of the Olivetti Programma 101 in the School of Physical Education at the University of Calgary.

Hypothesis

The null hypothesis was used as the basis for comparison

$$H_o: u_1 = u_2 = \ldots\ldots = u_k = u$$

This hypothesis assumed there were no experimentally significant effects as a result of different treatments applied to the groups:

1) That flexibility training had no significant effect on the repeated measures of performance time.
2) That sex of the subjects had no significant effect on repeated measures of arm strength scores.
3) That sex of the subjects had no significant effect on repeated measures of performance time.
4) That three types of strength training had no significant effect on repeated measures of performance time.
5) That three types of strength training had no significant effect on repeated measures of arm strength scores.

CHAPTER IV

RESULTS AND DISCUSSION

Analysis of the data is presented in the following subsections: subject data, flexibility effect, sex effect, performance on strength tests, performance on swimming tests and correlation between changes in strength and changes in swimming performance.

Subject Data

The age, strength scores and swimming times are presented for the three different training groups and the total sample in Tables I, II, III and IV. Analyses of variance were performed on all variables except age of the subjects.

Table V shows the results of analysis of variance for pre-training swimming times. There were no significant differences (P=.05) between the means for pre-training swimming times of the three training groups.

In Table VI, the summary for pre-training arm strength is shown. There were no significant differences (P=.05) between the means of the three training groups for pre-training arm strengths.

Table VII presents the summary for post-training swimming times. There were no significant differences (P=.05) between the means of the three training groups for the post-training swimming times.

TABLE I

MEAN, STANDARD DEVIATION, AND RANGE OF AGE, INITIAL STRENGTH, FINAL STRENGTH, INITIAL TIME AND FINAL TIME OF N=14 SUBJECTS IN CONTROL TRAINING GROUP

VARIABLE	$\bar{x}$	S.D.	RANGE
Age (months)	122.42	14.64	89 - 143 (54)
Initial Strength (lbs.)	37.14	7.55	31 - 59 (28)
Final Strength (lbs.)	45.28	14.19	31 - 71 (40)
Initial Time (secs.)	122.79	13.76	107.5 - 154.9 (47.4)
Final Time (secs.)	108.23	11.90	94.9 - 133.9 (39.0)

TABLE II

MEAN, STANDARD DEVIATION, AND RANGE OF AGE, INITIAL STRENGTH FINAL STRENGTH, INITIAL TIME AND FINAL TIME OF N=15 SUBJECTS IN ISOMETRIC TRAINING GROUP

VARIABLE	$\bar{x}$	S.D.	RANGE
Age (months)	122.60	13.56	98 - 141 (43)
Initial Strength (lbs.)	38.53	5.67	30 - 49 (19)
Final Strength (lbs.)	45.86	11.92	33 - 67 (34)
Initial Time (secs.)	119.60	17.59	100.8 - 163.2 (62.4)
Final Time (secs.)	103.94	15.21	86.4 - 150.5 (64.1)

TABLE III

MEAN, STANDARD DEVIATION, AND RANGE OF AGE, INITIAL STRENGTH FINAL STRENGTH, INITIAL TIME AND FINAL TIME OF N=17 SUBJECTS IN DYNAMIC TRAINING GROUP

VARIABLE	$\bar{x}$	S.D.	RANGE
Age (months)	124.82	16.17	89 - 147 (58)
Initial Strength (lbs.)	36.52	3.64	30 - 43 (13)
Final Strength (lbs.)	48.41	14.15	32 - 88 (56)
Initial Time (secs.)	117.72	12.61	90.3 - 140.2 (49.9)
Final Time (secs.)	104.55	11.51	86.6 - 133.7 (47.1)

TABLE IV

MEAN, STANDARD DEVIATION, AND RANGE OF AGE, INITIAL STRENGTH, FINAL STRENGTH, INITIAL TIME AND FINAL TIME OF N=46 SUBJECTS IN ALL GROUPS COMBINED

VARIABLE	$\bar{x}$	S.D.	RANGE
Age (months)	123.36	14.61	89 - 147 (58)
Initial Strength (lbs.)	37.36	5.67	30 - 59 (29)
Final Strength (lbs.)	46.64	13.48	31 - 88 (57)
Initial Time (secs.)	119.83	14.42	90.3 - 163.2 (72.9)
Final Time (secs.)	105.47	13.16	86.4 - 150.5 (64.1)

TABLE V

ANALYSIS OF VARIANCE SUMMARY TABLE FOR PRE-TRAINING TIMES

SOURCE OF VARIATION	SS	df	MS	F
Between Groups	199.500	2	99.75	0.46
Within Groups	9,353.688	43	217.53	
Total	9,553.188	45		

F of 19.47 needed for significance at .05

TABLE VI

ANALYSIS OF VARIANCE SUMMARY TABLE FOR PRE-TRAINING STRENGTH

SOURCE OF VARIATION	SS	df	MS	F
Between Groups	33.031	2	16.52	0.51
Within Groups	1,403.687	43	32.64	
Total	1,436.718	45		

F of 19.47 needed for significance at .05

TABLE VII

ANALYSIS OF VARIANCE SUMMARY TABLE FOR POST-TRAINING TIMES

SOURCE OF VARIATION	SS	df	MS	F
Between Groups	156.375	2	78.19	0.47
Within Groups	7,204.500	43	167.55	
Total	7,360.875	45		

F of 19.47 needed for significance at .05 level

TABLE VIII

ANALYSIS OF VARIANCE SUMMARY TABLE FOR POST-TRAINING STRENGTH

SOURCE OF VARIATION	SS	df	MS	F
Between Groups	88.000	2	44.00	0.24
Within Training Groups	7,818.750	43	181.83	
Total	7,906.750	45		

F of 19.47 needed for significance at .05 level

The means of post-training arm strength scores are presented in Table VIII. There were no significant differences (P=.05) between the post-training arm strength scores of the three training groups.

Flexibility Effect

The two flexibility training groups consisted of subjects who either performed the flexibility exercises or did not perform the flexibility exercises, depending on which sub-group for flexibility to which they were assigned (Appendix C).

Table IX shows the summary of a two way ANOVA of flexibility training and repeated measures of swimming times for the two groups. There were no significant differences between the two flexibility training groups for group mean times of initial and final trials, but there was a significant difference between initial and final times summed for both groups (P=.01).

Table X presents the initial and final mean swimming times, standard deviation, difference between the means, standard error and t-ratio for the total group of 23 trained on flexibility, and for the total group of 23 with no flexibility training. The differences between initial and final times were significantly different at the .01 level for both groups. The difference between initial and final times were not significantly different from one group to the other.

Table XI presents the summary of a two way ANOVA of flexibility training and swimming times for the control group only.

TABLE IX

ANALYSIS OF VARIANCE SUMMARY TABLE FOR FLEXIBILITY EFFECT
ON SWIMMING TIME OF ALL GROUPS COMBINED

SOURCE OF VARIATION	SS	df	MS	F
Flexibility Training Groups	36.656	1	36.656	0.105
Error (a)	15,428.000	44	350.636	
Initial Vs. Final Trials (Times)	4,771.781	1	4,771.781	144.999*
Group x Trial Interaction	0.359	1	0.359	0.011
Error (b)	1,448.000	44	32.909	
Total	21,684.796	91		

* denotes significance at .01 level

F of 7.24 needed for significance at .01

TABLE X

INITIAL MEAN TIME ($\bar{x}_i$), STANDARD DEVIATION, FINAL MEAN TIME ($\bar{x}_f$), STANDARD DEVIATION DIFFERENCE OF THE MEANS, STANDARD ERROR AND t RATIO FOR 2 GROUPS N=23 ONE TRAINED ON FLEXIBILITY AND THE OTHER NOT TRAINED ON FLEXIBILITY

GROUP	$\bar{x}_i$	S.D.	$\bar{x}_f$	S.D. DIFF. $(\bar{x}_i - \bar{x}_f)$		S.E.	t
No Flexibility Training	120.51	16.08	106.42	13.26	14.09	4.13	3.41 *
Flexibility Training	119.29	13.20	104.78	12.56	14.51	3.69	3.96 *

* denotes significance at .01

TABLE XI

ANALYSIS OF VARIANCE SUMMARY TABLE FOR FLEXIBILITY EFFECT ON SWIMMING TIME OF CONTROL GROUP ONLY

SOURCE OF VARIATION	SS	df	MS	F
Flexibility Training Group	301.109	1	301.109	1.087
Error (a)	3,324.437	12	277.120	
Initial Vs. Final Trials (Times)	1,483.453	1	1,483.453	26.992*
Group x Trial Interaction	17.281	1	17.281	0.314
Error (b)	695.500	12	54.958	
Total	5,821.780	27		

* denotes significance at .01 level

F of 4.75 needed for significance at .01

TABLE XII

INITIAL MEAN TIME ($\bar{x}_i$), STANDARD DEVIATION, FINAL MEAN TIME ($\bar{x}_f$), STANDARD DEVIATION, DIFFERENCE OF THE MEANS, STANDARD ERROR AND t RATIO FOR TWO GROUPS N=7 OF CONTROLS, ONE TRAINED ON FLEXIBILITY AND ONE NOT TRAINED ON FLEXIBILITY

GROUP	$\bar{x}_i$	S.D.	$\bar{x}_f$	S.D.	DIFF. $(\bar{x}_i - \bar{x}_f)$	S.E.	t
No Flexibility Training	126.93	17.51	110.72	13.23	16.21	6.70	1.95 *
Flexibility Training	118.71	8.36	105.69	10.72	13.02	5.15	2.52 *

* denotes significance at .05

TABLE XIII

ANALYSIS OF VARIANCE SUMMARY TABLE FOR EFFECTS OF FLEXIBILITY AND SEX ON FINAL TIMES OF ALL GROUPS COMBINED

SOURCE OF VARIATION	SS	df	MS	F
Flexibility Training Groups	60.181	1	60.181	0.357
Sex of Subjects	71.401	1	71.401	0.424
Error (a and b)	7,248.500	43	168.570	
Flexibility x Sex Interaction	53.938	1	53.938	0.315
Error (interaction)	7,194.560	42	171.299	
Total	14,628.580	88		

* denotes significance at .05 level

F of 251 needed for significance at .05

There was a significant difference (P=.01) between initial and final times summed for both halves of the control group, but no significant difference in the initial and final times between the two flexibility treatments in the control group.

Table XII presents the initial and final mean swimming times, standard deviations, difference between the means, standard error and t-ratio for the control group of seven trained on flexibility and for the control group of seven with no flexibility training. The differences between initial and final times were significantly different at the .05 level for both groups, but the differences between initial and final times were not significantly different from one group to the other.

Table XIII displays the summary of a two way ANOVA of flexibility and sex effect on final times of all groups combined. There was no significant difference between the group means of final swimming time for the male and female groups. There was no significant difference between the group means of final swimming time for the groups trained with flexibility and the groups trained without flexibility. The interaction of sex and flexibility was not significant with respect to final swimming times of the groups.

Sex Effect

In the previous subsection it was noted that sex of the subjects and flexibility training showed no significant interaction

with respect to the final swimming times, as shown in Table XIII.

Table XIV presents the summary of the three way ANOVA of sex versus strength training method versus initial and final arm strength measures. There was no significant difference in the initial and final mean arm strength measures of the female subjects as opposed to the male subjects. There was no significant difference in the initial and final mean arm strength measures of the control group, the isometric group and the dynamic group. There were small and insignificant F ratios for the interactions of sex and strength training method (F=.14), sex and repeated measures of strength (F=.50) and sex and strength training method on repeated measures of strength (F=.18). There was a significant difference (P=.01) between initial and final arm strength trials summed for all groups.

Table XV presents the initial and final mean arm strengths and the t-ratio of the differences between them, for the total number of 23 female subjects in all training groups and the total number of 23 male subjects in all training groups. The difference between initial and final arm strengths were significantly different at the .01 level for both groups summed. There were no significant differences between groups.

A summary table for the three way ANOVA of sex and strength training method on initial and final swimming times is presented in Table XVI. There was no significant difference in the initial and final mean swimming times of the female subjects as compared with

TABLE XIV

ANALYSIS OF VARIANCE SUMMARY TABLE FOR EFFECTS OF SEX COMPARED WITH TRAINING METHOD AND REPEATED MEASURES OF ARM STRENGTH

SOURCE OF VARIATION	SS	df	MS	F
Sex of Subjects	204.313	1	204.313	1.45
Strength Training Methods (STM)	24.063	2	12.031	0.09
Sex x STM Interaction	38.563	2	19.281	0.14
Error	5.059.313	36	140.536	
Initial Vs. Final Trials (Strength)	1,656.313	1	1656.313	17.49*
Sex x Repeated Measures Interaction	47.250	1	47.250	0.50
STM x Repeated Measures Interaction	25.125	2	12.563	0.13
Sex x STM x Repeated Measures Interaction	34.813	2	17.406	0.18
Error	3,409.000	36	94.694	
Total	10,498.753	83		

* denotes significance at .01 level

F of 7.39 needed for significance at .01 level

TABLE XV

INITIAL MEAN ARM STRENGTH ($\bar{x}_i$), STANDARD DEVIATION, FINAL MEAN ARM STRENGTH ($\bar{x}_f$) STANDARD DEVIATION, DIFFERENCE OF THE MEANS, STANDARD ERROR AND t FOR TOTAL FEMALE SUBJECTS N=23 AND TOTAL MALE SUBJECTS N=23

GROUP	$\bar{x}_i$	S.D.	$\bar{x}_f$	S.D.	DIFF. $(\bar{x}_f - \bar{x}_i)$	S.E.	t
Female Subjects	36.70	4.14	44.39	11.88	7.69	2.61	2.94 *
Male Subjects	38.04	6.87	48.83	14.47	10.79	3.34	3.23 *

* denotes significance at the .01 level

TABLE XVI

ANALYSIS OF VARIANCE SUMMARY TABLE FOR EFFECTS OF SEX AND TRAINING METHOD ON REPEATED MEASURES OF SWIMMING TIME

SOURCE OF VARIATION	SS	df	MS	F
Sex of Subjects	161.000	1	161.000	0.40
Strength Training Methods (STM)	292.000	2	146.000	0.36
Sex x STM Interaction	397.000	2	198.500	0.49
Error	14,496.000	36	402.666	
Initial Vs. Final Trials (Times)	4,337.000	1	4,337.000	140.79*
Sex x Repeated Measures Interaction	15.000	1	15.000	0.49
STM x Repeated Measures Interaction	57.000	2	28.500	0.93
Sex x STM x Repeated Measures Interaction	187.000	2	93.500	3.04
Error	1,109.000	36	30.806	
Total	21,051.000	83		

* denotes significance at .01 level

F of 7.39 needed for significance at .01 level

TABLE XVII

INITIAL MEAN TIME ($\bar{x}_i$), STANDARD DEVIATION, FINAL MEAN TIME ($\bar{x}_f$), STANDARD DEVIATION DIFFERENCE OF THE MEANS, STANDARD ERROR AND t FOR TOTAL FEMALE SUBJECTS N=23 AND TOTAL MALE SUBJECTS N=23

GROUP	$\bar{x}_i$	S.D.	$\bar{x}_f$	S.D.	DIFF. ($\bar{x}_i$-$\bar{x}_f$)	S.E.	t
Female Subjects	121.05	16.25	106.42	13.78	14.63	4.43	3.30 *
Male Subjects	118.70	12.91	105.14	11.81	13.56	3.64	3.72 *

* denotes significance at the .01 level

the male subjects. There was a small statistically insignificant difference in the initial and final mean swimming times of the control group, the isometric group and the dynamic group. There were small and insignificant F ratios for the interactions of sex and strength training method (F=.49), sex and repeated measures of swimming time (F=.49), and sex and strength training method on repeated measures of swimming time (F=3.04). There was a significant difference at the .01 level of confidence, between initial and final swimming trials summed for all groups.

Table XVII presents the initial and final mean swimming times and the t-ratio of the differences between them, for the total number of 23 female subjects in all training groups and the total number of 23 male subjects in all training groups. The differences between initial and final arm strength were significant at the .01 level for both males and females. There was no significant difference between the two groups.

Strength Tests

The summary of the two way analysis of variance of training method versus initial and final measures of arm strength is presented in Table XVIII. The three strength training groups of control, isometric and dynamic comprised of male and female subjects within each group did not differ significantly in their mean changes from initial to final measures of arm strength (F=.526). There were no

TABLE XVIII

ANALYSIS OF VARIANCE SUMMARY TABLE FOR EFFECT OF TRAINING METHOD ON REPEATED MEASURES OF ARM STRENGTH

SOURCE OF VARIATION	SS	df	MS	F
Between Training Methods (a)	26.661	2	13.330	0.103
Error (a)	5,560.063	43	129.304	
Initial Vs. Final Strength (b)	1,900.530	1	1,900.530	22.314*
Training Method x Trial Interaction	89.563	2	44.782	0.526
Error (b)	3,662.375	43	85.172	
Total	11,239.192	91		

* denotes significance at .01 level

F of 7.26 needed for significance at .01 level

TABLE XIX

INITIAL MEAN ARM STRENGTH ($\bar{x}_i$), STANDARD DEVIATION, FINAL MEAN ARM STRENGTH ($\bar{x}_f$) STANDARD DEVIATION, DIFFERENCE OF THE MEANS, STANDARD ERROR AND t FOR CONTROL N=14, ISOMETRIC N=15, AND DYNAMIC N=17 TRAINING

GROUP	$\bar{x}_i$	S.D.	$\bar{x}_f$	S.D.	DIFF. $(\bar{x}_f - \bar{x}_i)$	S.E.	t
Control	37.1	7.55	45.3	14.20	8.2	3.81	2.15 (a)
Isometric	38.5	5.67	45.9	11.30	7.4	3.39	2.18 (a)
Dynamic	36.5	3.64	48.4	14.16	11.9	3.54	3.36 *

(a) denotes significance at the .05 level

* denotes significance at the .01 level

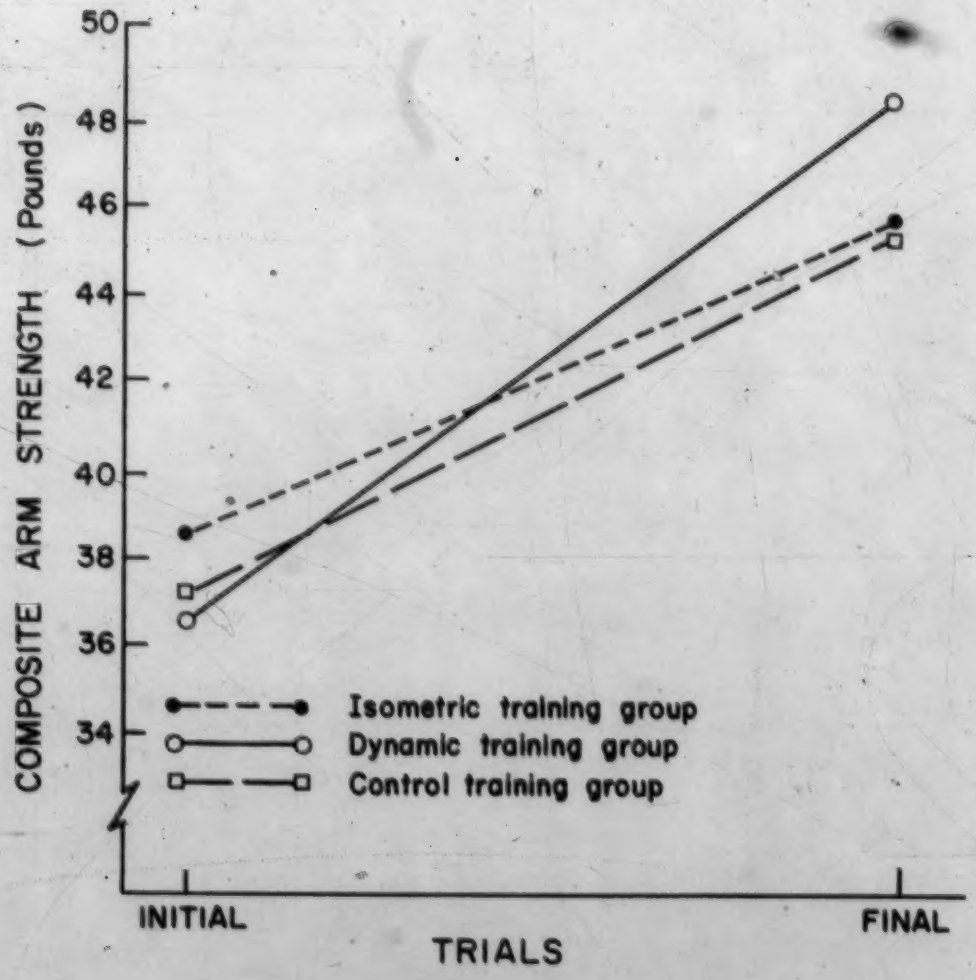

Figure 7 - Arm strength changes over the eight week training period.

significant differences between the groups in initial and final mean arm strength measures (F=.103). There was a significant difference at the .01 level from initial to final arm strength measures for all groups summed together (F=22.314).

Table XIX presents the initial and final mean arm strengths, standard deviations, difference of the means, standard error and the t-ratio for the three different strength training groups. The control group and the isometric group showed an increase from initial to final measures of arm strength significant at the .05 level. The control groups arm strength increased by 22.1% from initial to final measures. The isometric group's change from an initial arm strength (38.5 pounds) to a final arm strength (45.9 pounds) was an increase of 19.2%. The dynamic group mean showed an increase of 32.6% from an initial arm strength of 36.5 pounds to a final arm strength of 48.4 pounds. There were no significant differences between the mean changes in arm strength of the three training groups. Although dynamic strength increases were 13.4% greater than isometric the large standard deviations of the samples made this non-significant. The results are shown graphically in Figure 7. The small interaction illustrated was not significant at .05 level of confidence.

Performance on Swimming Tests

The summary of a two way analysis of variance of training method versus initial and final measures of swimming time is presented

in Table XX. The mixed male and female control group, isometric group and dynamic group did not differ significantly from each other in mean times for initial and final swimming trials (F=.484). The control, isometric and dynamic groups composed of both male and female subjects did not differ significantly (F=.359) in their group mean change in swimming time from initial to final trials. There was a very significant difference at the .01 level from initial to final arm strength measures for all groups summed together (F=144.308).

Table XXI shows the initial and final swimming times, standard deviations, differences of the means, standard error and the t-ratio for the three strength training methods. All three groups showed a significant increase, at the .01 level, from initial to final trials of swimming time. The control group's initial (122.8 seconds) to final (108.2 seconds) change was an improvement of 11.9%. The isometric group improved from 119.6 seconds initially, to 103.9 seconds finally for a change of 13.1% over the duration of the experimental period. The dynamic group showed an improvement of 12.0% from the initial time trial (117.7 seconds) to the final trial (104.6 seconds). There were no significant differences between the mean changes of the three groups. The results are presented graphically in Figure 8. The small interaction illustrated between the isometric and control group was insignificant, when the large standard deviations and small sample sizes were considered.

TABLE XX

ANALYSIS OF VARIANCE SUMMARY TABLE FOR EFFECT OF TRAINING METHOD ON REPEATED MEASURES OF SWIMMING TIME

SOURCE OF VARIATION	SS	df	MS	F
Between Training Methods (a)	340.876	2	170.438	0.484
Error (a)	15,134.000	43	351.933	
Initial Vs. Final Time (b)	4,778.938	1	4,778.938	144.308*
Training Method x Trial Interaction	23.804	2	11.902	0.359
Error (b)	1,424.000	43	33.116	
Total	21,701.618	91		

* denotes significance at .01 level

F of 7.26 needed for significance at .01 level

TABLE XXI

INITIAL MEAN TIME ($\bar{x}_i$), STANDARD DEVIATION, FINAL MEAN TIME ($\bar{x}_f$), STANDARD DEVIATION DIFFERENCE OF THE MEANS, STANDARD ERROR AND t RATIO, FOR CONTROL N=14 ISOMETRIC N=15, AND DYNAMIC N=17, TRAINING GROUPS

GROUP	$\bar{x}_i$	S.D.	$\bar{x}_f$	S.D.	DIFF. $(\bar{x}_i - \bar{x}_f)$	S.E.	t
Control	122.79	13.76	108.23	11.90	14.56	4.68	3.11 *
Isometric	119.60	17.59	103.94	15.21	15.66	5.81	2.70 *
Dynamic	117.72	12.65	104.55	11.51	13.17	4.04	3.24 *

* denotes significance at .01 level

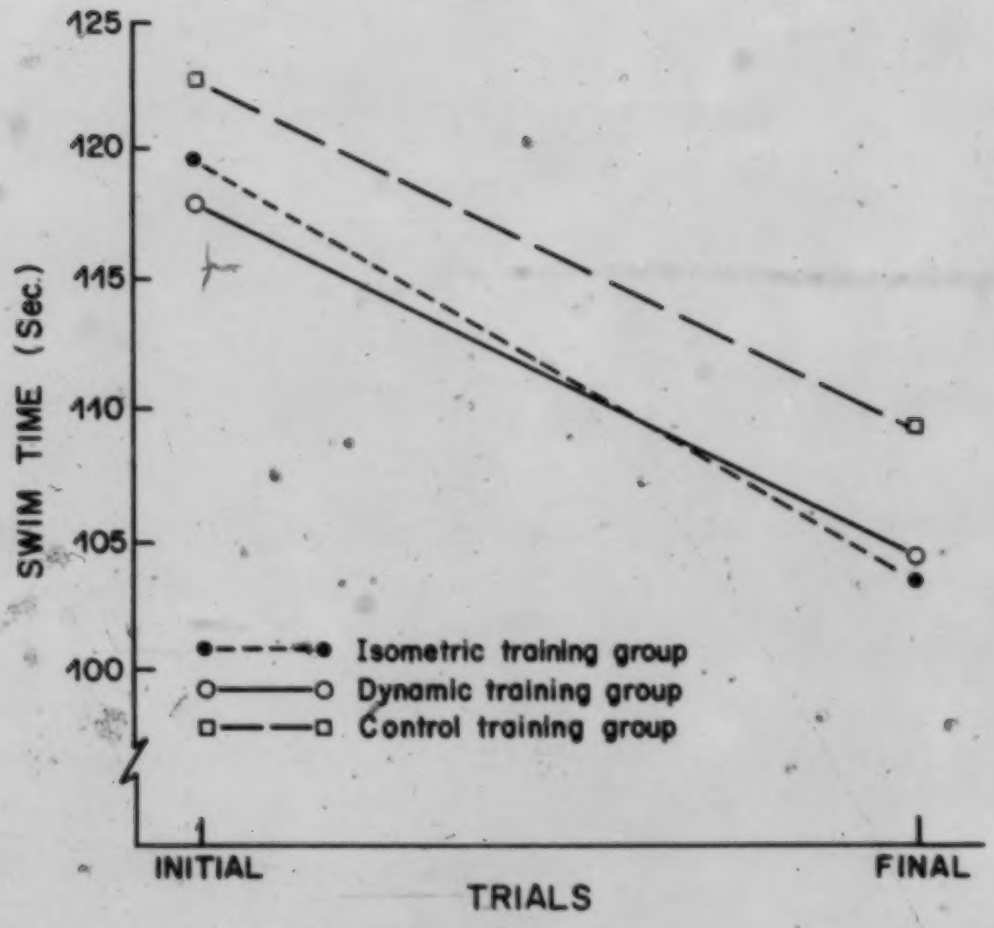

Figure 8 - Swimming time changes over the eight week training period.

The Correlation of Arm Strength to Swimming Speed

For the total group of 46 subjects, Pearson's Product Moment technique was used to determine the correlation coefficient between initial arm strength and initial swimming speed. The correlation coefficient was quite low (r=.14) suggesting that there was no more than chance correlation between the levels of strength and speed of swimming.

The same technique was used on the 46 male and female subjects for the correlation between final arm strength and final swimming speed. This correlation coefficient was slightly higher (r=.26), but still not significantly different from chance correlation at the .05 level. A very low correlation coefficient (r=.08) was obtained for the increase in arm strength to difference in swimming time from initial to final trials for the 46 subjects. This correlation was also insignificant at the .05 level.

Discussion

Initial analysis of the data for flexibility effect on the total sample of 46, showed no significant difference between the mean swimming times for the 23 subjects who participated in flexibility training as opposed to the 23 subjects who did not participate in flexibility training. Both groups improved significantly (P=.01) from initial to final trials of swimming time. It was reasonable to assume that if there was an effect due to flexibility, it might have been masked by the effects of

the three strength training methods.

If the flexibility effect was present, it could be expected to be most marked in the control group where there would be no interaction effect with isometric or dynamic training. Subsequent analysis of the subjects in the control group who trained with flexibility as opposed to those control group subjects who did not train with flexibility, showed no significant difference between the flexibility trained subjects and the subjects not trained on flexibility, although both groups improved on initial to final swimming times (P=.05). The flexibility and sex effect did not interact significantly on the final swimming times (see Table XIII).

The analysis of sex effect and training method on repeated measures of arm strength showed no significant differences of mean arm strength changes between sex of the subjects and strength training method. There was, however, a significant difference (P=.01) between initial and final arm strength trials for all subjects combined.

The consideration of sex and training method on repeated trials of swimming performance time yielded results very similar to those for arm strength. There were no significant differences of mean swimming time changes between sex and between training method. All of the groups had significant differences in swimming times from initial to final trials.

It was found that in analysing the total isometric (N=15), dynamic (N=17), and control (N=14) groups that the mean gains of arm

strength and swimming speed were significant (P=.01) within the isometric and dynamic strength training groups and in the control group. There were no significant differences between the three different strength training groups for amount of improvement of arm strength with the control group, the isometric group and the dynamic group improving 22.1%, 19.2% and 32.6% respectively. There were no significant differences between the three different strength training groups for amount of time improvement in swimming a 100 metre freestyle under competitive conditions, with the control group, isometric group and dynamic group improving 11.9%, 13.1% and 12.0% respectively.

The correlation of initial and final arm strength with initial and final swimming speeds for 46 subjects yielded small and statistically insignificant correlation coefficients of r=.14 and r=.26 respectively. The correlation between changes in strength and changes in swimming time was very low at r=.08. The reliability coefficient for two different measures of initial composite strength for the 46 subjects was satisfactory at r=.91. These low correlations tend to indicate that speed of swimming in novice swimmers is less dependent on strength than on a "feel for the water" or an inate swimming efficiency.

The results of this study agree with Kerr (56a) and Scott (83) who found that dynamic and isometric strength training methods yielded the same strength gains. The failure of either strength

training method to show superiority over the controls for either strength gain or swimming performance may be explained by the possibility that swimming training alone was sufficient to stimulate the increase in strength and in swimming speed. This may be particularly true of first year competitive swimmers who may be applying greater force to move through the water at the same speed as a swimmer with more efficient stroke mechanics. Perhaps until swimmers have attained a level of stroke efficiency where corrections of major mistakes are no longer necessary, the addition of a dry land strength training program is of less value than actual direct practice of swimming training in the water. For this reason the choice of swimmers with one or two years of competitive swimming experience may yield more definitive results for the comparison of isometric and dynamic strength training programs on swimming performance.

The results of this study may well have been affected by the two week break between the first four weeks and the last four weeks of the strength training and swimming program. Muller (67), however, reported that bi-weekly maximal contractions performed once only are sufficient to maintain a given level of strength. Thus the last maximal contraction of the first four week period should have maintained the strength level of the subjects over the two week break.

There may have been a more significant interaction between the different training programs had the experimental period been

extended for the whole of the swimming season from October to May with two or three intermediate measures of strength and swimming time.

It was assumed by the investigater that the initial seven week orientation period consisting of swimming training only would serve the purpose of eliminating the early variance in learning the motor task of swimming the stroke (1). It is possible that the individual response to the swimming training alone may have changed the relative strength levels of the subjects before the start of strength training. This would have affected the relative improvement of the isometrically and dynamically trained group, when compared with the control group trained on active swimming practice only.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The primary purpose of this study was to determine the relative effects of isometric and dynamic strength training, and a controlled non-strength training program on the performance of pre-pubescent (7 years to 12 years) competitive swimmers, for a 100 metre front crawl swim. Subproblems were the effect of a series of non-resistive flexibility exercises on swimming performance, and the effect of the sex of the subjects in response to the three strength training programs as measured by arm strength and swimming timed performance improvement.

Fifty-four first year competitive swimmers were assigned to six groups of nine each, on the basis of initial swimming time performance and age. Eight swimmers did not complete the program leaving: a control group of seven, a control group of seven with flexibility exercises, an isometric group of seven, an isometric group of eight with flexibility exercises, a dynamic group of nine and a dynamic group of eight with flexibility exercises. The analysis was conducted on swimming time (to the nearest tenth of a second) and on force (to the nearest pound), which was the composite of the average of two arm strength measures for each arm taken individually in the simulated mid position of the front crawl stroke. The analysis of variance technique was used to assess the effect of the different

variables of sex, flexibility exercise and strength training method on changes of swimming time and changes in arm strength for the duration of the experimental training period. Pearson's Product Moment technique was used to correlate the arm strength measures and swimming times. The following results were found:

1. The inclusion of flexibility training had no effect on the improvement of performance time in the 100 metre front crawl (freestyle) stroke.
2. Mean gains of arm strength for the female subjects were the same as mean gains of arm strength for the male subjects over the period of eight weeks of training.
3. Mean improvement of swimming time for the female subjects was the same as mean improvement of swimming time for the male subjects over the eight week training period.
4. There were no significant differences between the mean gains of arm strength for the isometrically trained group, the dynamically trained group and the control group, over the eight week training period. All groups improved significantly ($P=.05$).
5. There were no significant differences between the mean improvements of swimming time for the isometrically trained group, the dynamically trained group and the control group over the eight week training period. All groups improved ($P=.01$).

6. There was a low and non-significant positive correlation between initial arm strength scores and initial swimming speed (r=+.14).
7. There was a low and non-significant positive correlation between final arm strength scores and final swimming speed (r=+.26).
8. There was a low and non-significant negative correlation between change in arm strength scores and change in swimming times (r=-.08).

Conclusions

In conclusion, there were significant improvements of arm strength score and swimming time for all training groups with no single training method more effective than the other two groups. There were no differences in the response of males and females to the three different strength training programs. There were no significant differences in improvement of swimming time between the subjects who had flexibility training and those who did not have flexibility training. There were no significant correlations between arm strength as measured by tensiometry and swimming speed performance in these subjects. It would seem that strength is not as important and the endurance gained from actual swimming training.

Recommendations

Further study into this area is necessary to corroborate findings on the effects of isometric and dynamic strength training

on young swimmers between the ages of seven and twelve years. The results of this study appear to point to a greater value for actual swimming practice as opposed to strength training programs, for these age groups, when there is a limited amount of facility time available for both training procedures.

It seems that further studies would do well to extend the experimental period beyond twelve weeks. There would be less diversity of the subjects in future studies, if the subjects were chosen from a group of second or third year competitive pre-pubescent swimmers. This would tend to minimize the effects of mechanical corrections in strokes, since these swimmers are apt to be more familiar with correct stroke and training techniques and thus make any changes due to strength training method more apparent.

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APPENDIX A

CALIBRATIONS FOR THE CABLE TENSIOMETER

Following are the calibrations of the cable tensiometer from the University of Alberta, Serial #10185, using riser #1 and an 1/8 inch diameter cable.

READING	POUNDS TENSION	READING	POUNDS TENSION
0	15	20	40
1	17	21	41
2	18	22	42
3	19	23	44
4	20	24	46
5	21	25	47
6	22	26	48
7	23	27	49
8	24	28	51
9	25	29	52
10	26	30	53
11	28	31	54
12	29	32	56
13	31	33	58
14	32	34	60
15	33	35	61
16	34	36	62
17	36	37	63
18	38	38	65
19	39	39	67

READING	POUNDS TENSION	READING	POUNDS TENSION
40	68	46	77
41	69	47	78
42	70	48	80
43	72	49	82
44	74	50	84
45	76		

APPENDIX B

FLEXIBILITY EXERCISES

AND

ACCOMPANYING INSTRUCTIONS

FLEXIBILITY EXERCISES

1. a) Forward Arm Circles

Using both arms at once do forward arm circles at moderate speed. Emphasize the upward lifting motion and the shoulder rotation 10X.

b) Backward Arm Circles

Same instructions as above. 10X

2. Hands Crossed Shoulder Stretch

Stand up straight and cross your hands over top of your head with your arms straight. Hold your arms as far back as they will go. 10 secs.

3. Wall Assisted Shoulder Stretch

Keep your hands crossed over your head and bend forward toward a wall, using it to keep your arms up while you push your head and body as low as possible. 10 secs.

4. Ankle Looseners

Place your legs under your seat with your feet pointed straight back. Stretch backward touching your head to the floor. 10 secs.

5. Gastrocnemius Looseners

Face a wall at arms length away with your feet placed shoulder width apart. Hold your arms out to touch the wall and slowly bend your arms and touch the wall with your chest while keeping your heels on the ground and your knees straight. 10 secs.

6. Whip Kick Ankle and Knee Stretch

Take the same basic position as in #4 except point your feet out to the side and point them up towards your knees. Keep your knees close together and settle as low as you can. 10 secs.

APPENDIX C

ASSIGNING OF ORIGINAL SUBJECTS

ASSIGNING OF ORIGINAL SUBJECTS

	Mean Age In Months	Standard Deviation	Mean Time In Seconds	Standard Deviation
Group 1 Control No Flexibility	117.6	18.6	119.1	12.1
Group 2 Isometric No Flexibility	116.9	14.7	117.7	16.9
Group 3 Dynamic No Flexibility	117.6	16.6	119.6	10.4
Group 4 Control Flexibility	118.9	11.3	122.4	15.4
Group 5 Isometric Flexibility	120.2	13.1	120.1	18.2
Group 6 Dynamic Flexibility	117.6	16.7	116.1	13.2

APPENDIX D

MEAN COMPOSITE SCORES FOR ARM STRENGTH

AND

SCORES FOR SWIMMING TIME

BEFORE AND AFTER TRAINING

MEAN COMPOSITE SCORES FOR ARM STRENGTH
AND SCORES FOR SWIMMING TIME
BEFORE AND AFTER TRAINING

	COMPOSITE ARM STRENGTH BEFORE	COMPOSITE ARM STRENGTH AFTER	SWIMMING TIME BEFORE	SWIMMING TIME AFTER
CONTROL WITH NO FLEXIBILITY				
E. Van Zant	43	41	110.3	96.4
M. Jonas	33	69	109.6	105.4
D. Anderson	38	39	137.6	111.3
D. Wagg	38	42	136.8	133.9
* N. Newton	32	51	154.9	116.8
* S. Kerr	34	71	111.3	95.7
* K. Adams	37	52	127.5	115.6
CONTROL WITH FLEXIBILITY				
D. Collins	59	65	110.8	97.1
E. Wren	31	31	118.8	108.8
* B. Christie	42	32	131.5	109.6
* L. Froome	37	42	116.5	94.9
* H. Rink	31	33	107.5	96.2
* W. Regent	40	30	119.7	103.0
B. Ansell	30	36	126.3	120.6

* denotes female subjects

MEAN COMPOSITE SCORES FOR ARM STRENGTH
AND SCORES FOR SWIMMING TIME
BEFORE AND AFTER TRAINING

	COMPOSITE ARM STRENGTH BEFORE	COMPOSITE ARM STRENGTH AFTER	SWIMMING TIME BEFORE	SWIMMING TIME AFTER
ISOMETRIC WITH NO FLEXIBILITY				
B. Clint	46	66	115.1	109.0
J. Luijkx	40	39	100.9	86.4
K. Bartley	39	44	117.1	98.0
C. Martin	32	37	100.8	92.6
B. Ross	36	65	141.4	104.5
* C. Roberts	36	41	106.2	92.9
* D. Rice	30	36	125.2	114.5
ISOMETRIC WITH FLEXIBILITY				
B. Mackinnon	49	56	120.4	105.0
G. Ahrens	30	33	119.9	100.0
* K. Ronald	36	50	143.0	114.3
* G. Gommerman	39	39	101.8	93.2
* S. Ashley	47	67	111.3	94.9
* J. Westman	40	37	111.1	104.2
* L. Miedema	39	42	116.6	99.2
* L. Riddell	39	36	163.2	150.5

* denotes female subjects

MEAN COMPOSITE SCORES FOR ARM STRENGTH AND SCORES FOR SWIMMING TIME BEFORE AND AFTER TRAINING

	COMPOSITE ARM STRENGTH BEFORE	COMPOSITE ARM STRENGTH AFTER	SWIMMING TIME BEFORE	SWIMMING TIME AFTER
DYNAMIC WITH NO FLEXIBILITY				
B. Junnilla	43	47	117.8	108.0
S. Grieves	32	88	90.3	86.6
H. Linville	37	42	129.0	113.5
C. Mackinnon	41	35	107.7	89.7
A. Regent	36	48	139.8	122.1
* H. Luther	36	41	110.9	102.2
* T. Ronald	38	63	113.0	102.4
* J. Sillner	34	32	127.5	110.1
* S. Riddell	30	30	140.2	133.7
DYNAMIC WITH FLEXIBILITY				
B. Lawrence	38	59	118.6	107.9
D. Kidd	41	56	120.2	100.9
D. Alexander	34	50	125.5	103.3
M. Hamilton	34	36	115.6	93.3
* S. Langley	37	58	106.7	100.0
* D. Ohlson	34	54	103.0	94.3
* M. Morrow	34	40	117.8	106.8
* L. Macmillan	42	44	117.8	102.6

* denotes female subjects